Reducing Risks in Wartime Through Capital-Labor Substitution: Evidence from World War II

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Abstract

This paper uses data from multiple archival sources to examine substitution among armored (tank-intensive), infantry (troop-intensive), and airborne (also troop-intensive) units, as well as mid-war reorganizations of each type, to estimate the marginal cost of reducing U.S. fatalities in World War II, holding constant mission effectiveness, usage intensity, and task difficulty. Assuming that the government equated marginal benefits and costs, this figure measures the implicit value placed on soldiers' lives. Our preferred estimates indicate that infantrymen's lives were valued in 2009 dollars between zero and \$0.5 million and armored troops' lives were valued between \$2 million and \$6 million, relative to the efficient \$1 million to \$2 million 1940s-era private value of life. We find that the reorganizations of the armored and airborne divisions both increased efficiency, one by reducing costs with little increase in fatalities and the other by reducing fatalities with little increase in costs.

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14. ABSTRACT
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Governments spend large amounts each year to increase the safety and effectiveness of ground combat troops; however, little is known about the degree to which such expenditures translate into measureable improvements in survival or combat success. Our research uses data from multiple archival sources to understand the economics of ground combat and tradeoffs made by American military planners between expenditures and U.S. deaths in one important historical context –the Western Front of World War II (WWII). The cost per life saved is estimated and used to infer the dollar value that the U.S. government placed on avoiding military deaths and determine how that valuation compared with the private Value of a Statistical Life (VSL) at the time – *i.e.*, citizens' willingness to pay for reductions in fatality risk (Thaler and Rosen, 1975; Viscusi, 1993, 1996).

U.S. Army Ground Forces were organized into divisions, military units consisting of 8,000 to 20,000 troops, that were infantry (troop-intensive), armored (tank-intensive), or airborne (*i.e.*, paratrooper, also troop-intensive). In late 1943, Army policies reduced the size of the armored division and slightly reduced the size of the infantry division. In early 1945, another Army policy increased the size of the airborne division. This study considers the effects of substitution across the different pre- and post-reorganization division types. Tank-intensive units were expensive in dollars, but troop-intensive units put more human targets on the battlefield; hence, an increase in tank-intensity would raise dollar costs and reduce fatalities. Supposing that the U.S. government equated marginal benefits and marginal costs, the marginal cost per reduction in fatalities measures the implicit value that the government placed on soldier's lives.

The data we use have been compiled from multiple sources and constitute the most extensive set of quantitative information available on military operations in a single war. Individual-level data on all 144,534 deaths to American ground divisions in WWII were hand-

typed from archival lists and combined with casualty rosters obtained from multiple government agencies. All Allied and Axis units' movements were transcribed from campaign histories and historical atlases to identify terrain, geographical progress, and which Allied and Axis units met in combat. Another set of archival sources was compiled to measure the costs of raising and operating different U.S. divisions in WWII. We also use data compiled by The Dupuy Institute from U.S. and German archival sources on both sides' combat experiences for 162 engagements.

The results from this study indicate that, at the tank-intensity levels of the infantry and airborne divisions, the marginal cost in 2009 dollars per life saved by increasing tank intensity was half a million dollars or less, as compared to VSL estimates of one to two million dollars for young men in 1940 (Costa and Kahn, 2004). At the higher tank-intensity level of the armored division, we find a higher cost per life saved that is generally greater than two million dollars. [3] Thus, our results suggest that the U.S. government implicitly undervalued infantrymen's lives and slightly overvalued armored personnel's lives relative to the private value of citizens at the time. We find that the reorganization of the armored division increased efficiency by reducing dollar costs with little increase in fatalities and that the reorganization of the airborne division increased efficiency by generating a large reduction in fatalities at a low cost.

[3] Notably, our research does not estimate the VSL for U.S. military personnel during WW II. It is more akin to the cost per life saved estimates used for various government regulations. It is unclear whether military members at the time valued their lives differently in comparison to non-military workers. Given the widespread reach of the draft, it is likely that they were roughly the same. Unfortunately, there does not appear to be any previous research on estimating the VSL for WW II military personnel. As for other conflicts, Rohlfs (2012) estimates an upper bound on the VSL for military recruits during the Vietnam era and finds values ranging from $7 million to $12 million (in 2009 dollars). In addition, recent estimates from Greenstone et al. (2014) suggest that modern day military members tend to implicitly value their lives at levels lower than average citizens. Also, given the limited amount of research in this area, it is not entirely clear whether military members have traditionally been under- or over-valued by the U.S. government relative to private citizens. That stated, the recent estimates in Rohlfs and Sullivan (2013), for modern day warfare, suggest that the U.S. government likely over-values military members in comparison to average citizens for certain types of armament programs. This may or may not be the case historically and this paper provides context for these types of questions.

In addition to measuring the U.S. government's valuation of soldiers' lives, this study adds to the tools available for empirical research in national defense. The WWII data used in this study describe a wide variety of combat situations and are unique among datasets from modern wars in that they include detailed first-hand information from both sides. Casualty forecasts using previously available WWII data have been more accurate than those based on less data-driven approaches (*Economist*, 2005), and the data and techniques introduced in this study could help to further improve the accuracy of many types of military policy evaluations.

II. Key Institutional Factors

After World War I, British military theorists advocated increasing the use of tanks to avoid the casualty-intensive stalemate of trench warfare (Fuller, 1928, pp. 106-151; Liddell Hart, 1925, pp. 66-77; Wilson, 1998, pg. 120). These theorists' ideas were influential in the Army and in Congress (U.S. Congress, 1932, pg. 9932). However, the Army was slow to adopt tanks due to conservatism among high-ranking officers and to Congressional budget cuts (Greenfield, Palmer, and Wiley, 1947, pp. 334-335; Steadman, 1982; Watson, 1950, pp. 15-50).

A. Determinants of Army-Wide Capital Intensity during World War II

During the war, military procurement was constrained by the size of the U.S. economy and population (Smith, 1959, pp. 136; 154-158); however, the procurement process was driven more by reasoned tradeoffs than by responses to immediate shortages (Harrison, 1988, pp. 181, 188-9). Constraints that the War Production Board imposed on materiel procurement were denominated in dollars and took into account "the needs of the civilian and industrial economy" (Smith, 1959, pg. 154-8). Most materiel purchases involved large contracts whose prices were

monitored to curb war profiteering (Smith, 1959, pp. 216-412) but appear to have been somewhat higher than those in the civilian economy.[4]

As with equipment, the procurement of troops involved a variety of tradeoffs. The Army adjusted its competency requirements depending on the need for troops, and Congress restricted the drafting of 18-year-olds and fathers in response to public sympathy but varied those restrictions depending on the needs of the war effort (Greenfield, Palmer, and Wiley, 1947, pp. 246-251; Palmer, Wiley, and Keast, 1959, pp. 45, 85, 201-207, 400).

B. Division Types and the Reorganizations

The division was the primary level at which U.S. Army Ground Forces were organized. Roughly two to four divisions comprised a corps, which was the next higher level of organization. Divisions from the same corps were rarely more than a few miles apart. Divisions' corps affiliations changed frequently over the course of the war, and a corps sometimes included divisions from multiple countries (Greenfield, Palmer, and Wiley, 1947, pg. 332; Kahn and McLemore, 1980, pp. 192-199).

The Army sent 16 armored divisions, 47 infantry divisions, and 4 airborne divisions to the Western Front. Armor was used offensively to exploit penetrations generated by infantry and often operated behind enemy lines but required large amounts of gasoline and had difficulty on wet or rugged terrain. Infantry was used in a wide set of offensive and defensive operations, and airborne divisions parachuted behind enemy lines to disrupt communications and supplies and to

[4] With all prices in 2009 dollars, in 1942, the Army paid $18,300 for a four-door sedan and $16,000 for a ¼-ton jeep (U.S. Army Service Forces, 1942). One source shows a new two-door sedan selling in the civilian economy in 1940 for $11,300; comparable new and used cars sold in nearby years for similar prices. In 1935, a used half-ton pickup truck was selling for $7,300, and in 1956, a new jeep was selling for $10,800 (Morris County Library, 2009).

initiate surprise attacks (Evans, 2002, pg. 49; Gabel, 1985a, pg. 4-6, 24; 1985b, pg. 4, 1986, pp. 4, 8, 12, 23; Rottman, 2006, pp. 6, 24-7; Stanton, 1984, pg. 8, 11; Zaloga, 2007, pp. 9-12).

Technological progress at the time allowed U.S. commanders to advance and maneuver their troops much faster during WW II in comparison to previous wars. The degree of movement, however, was largely dictated by the terrain, combat environment, and unit capabilities. The initial entry of U.S. forces into the war began in November, 1942 in Algeria and Morocco. Units traveled east across Africa, up to Tunis and Sicily, and continued up the length of Italy for the duration of the war. Additional Allied units invaded Northern France in June 1944 and Southern France in August 1944, both traveling eastward to Germany.

When the U.S. first entered the war, the number of troops in an organic or standard infantry division was 15,514, and the number in an organic armored division was slightly lower, at 14,643; the armored division also included 390 tanks. The airborne division was first introduced in October 1942 and included 8,505 troops, making it considerably smaller than the other division types. In July 1943, the Army slightly reduced the size of the infantry division to 14,253. In September 1943, the Army reduced the troops and tanks in the armored division to 10,937 and 263. In December 1944, the Army increased the number of troops in an airborne division to 12,979 (Wilson, 1998, pp. 162-9, 183-5, 197).

The actual numbers of troops and tanks in a division varied over time as subordinate units, such as regiments and battalions, were attached to and detached from different divisions. Attaching units was more common than detaching them, so that the numbers of troops and tanks in a division tended to be larger than the standard levels. Troops and tank levels also varied due to the lag between combat losses and the arrival of replacement troops and equipment.

All armored and infantry divisions that were raised after the reorganizations were given the new structure. All six infantry divisions already in the theater were reorganized in late 1943 or early 1944. Of the three armored divisions that were already in the theater, the 1st was reorganized in June, 1944. The 2nd and 3rd were kept under the old structure to avoid disrupting their preparation for the D-Day invasion and were not reorganized until after the end of the war. The airborne reorganizations all took place on March 1, 1945. Of the four airborne divisions – the 13th, 17th, 82nd, and 101st –that were sent to the Western Front, the attachments to the 82nd and 101st were sufficiently large prior to the reorganization that they were effectively under the larger structure since the start of the war (Stanton, 1984, pp. 5-19; Wilson, 1998, pp. 182-96).

III. Descriptive Results

The datasets used here include a daily panel constructed by us and a team of research assistants. The data include information about the overseas experiences of every U.S. division sent to the Western Front and a sample obtained from The Dupuy Institute of a more detailed set of variables for 289 division days from 162 engagements between U.S. and German forces. Additionally, data on the costs of raising and operating divisions of different types were compiled by the author from archival sources. Descriptions and summary statistics for these datasets appear in the appendix to this paper, and more detailed descriptions are provided in the web appendix.

Figure 1 shows numbers of U.S. troops, tanks, estimated cost, and combat outcomes by division type. Panels A and B show actual troop and tank levels from the engagement data. Within each panel, the left three bars are pre-reorganization levels and the right three bars are post-reorganization. The black bars correspond to armored divisions, the white bars to infantry

divisions, and the gray bars to airborne divisions. The 2nd and 3rd Armored Divisions are always treated as pre-reorganization, and the 82nd and 101st Airborne Divisions are always treated as post-reorganization.

As the engagement data illustrate, reorganization led to considerably smaller armored divisions. The reorganization reduced the typical armored division's numbers of troops and tanks from 20,000 and 467 to 15,100 and 218. This was in stark contrast to the impact of the reorganization's effect on the size of other division types. For instance, the reorganization appears to have had little impact on the size of infantry divisions. Unfortunately, the engagement data do not include information on the size of the pre-reorganization airborne units. We do find, however (in results not shown), that the organic and authorized troop level data indicate that the reorganization led to considerably larger airborne divisions.

Panel C combines the per troop and per tank estimates from the cost data with the troop and tank levels from panels A and B to estimate the cost of a 10.8-month deployment by division type.[5] From the engagement data, we find that the armored reorganization reduced the cost of that division type from $5.14 billion to $2.93 billion and that the infantry reorganization was associated with a slight increase in the cost of that division type from $2.20 billion to $2.29 billion.

Panels D, E, and F present various measures which illustrate how well U.S. troops performed in combat. These include kilometers (km) of progress along the attacker's axis of advance, U.S. killed in action (KIA), and a zero to one subjective index of mission success from The Dupuy Institute (2001b, 2005) for each of the division types.

[5] Light, medium, and heavy tanks are all treated equally in the cost calculations. The U.S. Army increased its percentage of medium versus light tanks over the course of the war and introduced a heavy tank design near the end of the war (Stubbs and Connor, 1969, pp. 63-6). In the engagement data, considering light tanks separately from medium and heavy tanks has little effect on the estimates in this study, as shown in the web appendix.

The differences between armored and infantry divisions in the panels suggest that armor was more effective than infantry in combat.[6] The two best proxy measures that we use for "mission accomplishment" – km advanced and the mission success index –tend to be higher for the armored divisions than for infantry. Also of interest (in results not shown) is that task difficulty appears to have been higher for armored divisions as well. While the number of troops in the opposing division was similar between pre-reorganization armor and infantry and somewhat lower for post-reorganization armor, the number of tanks in the opposing division was considerably higher for armor in both cases. U.S. KIA is slightly higher for armor than for infantry, which could be attributable to higher task difficulty or usage intensity for armor.

Despite the decrease in the armored division's troops and tanks, we observe a slight increase in km of progress and little effect on U.S. KIA. We see a negative effect of the armored reorganization on the index of mission success in panel F; however, suggesting that mission effectiveness may have declined in a way that is not captured by geographical progress. For the infantry reorganization, we observe slight increases in the mission success measure and in U.S. KIA,

Figure 2 illustrates the effects of these reorganizations on usage in combat, geographical progress, and U.S. KIA in the division by day panel. Panel A shows the average number of Axis divisions in the same 0.25 x 0.25-coordinate (about 15 by 15 mile) cell as the division and panel B shows the fraction of division days with five or more U.S. KIA. Airborne divisions had relatively high rates of exposure to Axis divisions, and infantry divisions had high numbers of days with five or more U.S. KIA. According to both definitions of days of combat, the armored and airborne reorganizations are associated with decreases in combat days for those division types, and the infantry reorganization is associated with an increase in combat days for that

[6] Regression results which duplicate the information in Figures 1 and 2 are available in in the web appendix.

division type. These changes in combat days are reflected in the outcome measures, km of progress and U.S. KIA, for the full sample in panels C and D. The armored reorganization is associated with a slight increase in progress and a large decrease in fatalities for that division type, a result that is consistent with a decline in days of combat or the difficulty of tasks for which the armored division was used. A similar and more pronounced pattern can be seen for the reorganization of the airborne division, a result consistent with a decline in combat days or task difficulty for that division type as well. The opposite pattern can be seen for the infantry reorganization, which is associated with a decline in progress and an increase in KIA, a finding that is consistent with an increase in combat days or task difficulty for infantry.

Panels E and F show the same outcome variables as in panels C and D; however, the sample is restricted to days in which the U.S. division was in the same geographic cell as one or more Axis divisions. For the division days with nearby Axis units in panels E and F, progress is similar for armored and airborne and is slightly lower for infantry divisions. Also, for division days with nearby Axis units, the results show U.S. KIA is highest for airborne units, followed by infantry and armored units, respectively. These findings are consistent with armor having the highest combat effectiveness, followed by infantry, and finally by airborne; however, the results are also consistent with task difficulty being the lowest for armor and the highest for airborne.

Notably, we see little effect of the decrease in armored division resources on progress or KIA. While this result could indicate that the change in troop and tank levels had no effect on usefulness in combat, it is also consistent with simultaneous declines in the armored division's usefulness in combat and the difficulty of tasks assigned to it. We see little effect of the infantry reorganization on progress or KIA during days of combat, which is unsurprising, given that the reorganization had little effect on the infantry division's resources. For the airborne division, the

reorganization is associated with a slight decline in progress and a large decline in KIA. This finding is consistent with a decline in usage intensity of the airborne division and either an increase in combat effectiveness or a decrease in task difficulty.

IV. Model

This next section develops a conceptual framework for understanding the observed differences among division types in costs, success, and fatalities and an econometric procedure for estimating the government's valuation of soldiers' lives. The cost minimization model used here is adapted from Rohlfs (2006a). Consider a country (or government) waging a war with M missions or campaigns. For each mission m, the government observes a vector $\mathbf{x_m^g}$ of pre-determined correlates of task difficulty and selects one of S unit organizational structures s_m and a usage intensity level $\imath_m$. The production functions for mission success Y_m and own fatalities F_m can be written as linear functions of these factors:

(1) $Y_m = \alpha_{s_m}^Y + \alpha_\imath^Y * \imath_m + \mathbf{x_m^g}'\boldsymbol{\beta}^\mathbf{Y} + \varepsilon_m^Y$, and

(2) $F_m = \alpha_{s_m}^F + \alpha_\imath^F * \imath_m + \mathbf{x_m^g}'\boldsymbol{\beta}^\mathbf{F} + \varepsilon_m^F$,

where $\alpha_{s_m}^Y$ and $\alpha_{s_m}^F$ are constant terms that are specific to organizational structure s_m and ε_m^Y and ε_m^F are error terms representing unobserved determinants of difficulty.

Organizational structure is correlated with usage intensity, which the researcher does not observe. Let $\imath_m = \gamma_{s_m} + \mathbf{x_m^g}'\boldsymbol{\beta}^\imath$ denote the usage intensity that the country would select for structure s_m and vector $\mathbf{x_m^g}$, a function that we assume is linear. Suppose that $\mathbf{x_m^g}$ can be partitioned into vectors $\mathbf{x_m^o}$ and $\mathbf{x_m^u}$, where the researcher observes $\mathbf{x_m^o}$. Substituting, we obtain:

(1')$Y_m = \alpha_{s_m}^{*Y} + \mathbf{x_m^o}'\boldsymbol{\beta}^{*\mathbf{oY}} + \varepsilon_m^{*Y}$, and

(2')$F_m = \alpha_{s_m}^{*F} + \mathbf{x_m^o}'\boldsymbol{\beta}^{*\mathbf{oF}} + \varepsilon_m^{*F}$,

where $\boldsymbol{\beta}^{A\prime} = [\boldsymbol{\beta}^{\mathbf{o}A\prime} \quad \boldsymbol{\beta}^{\mathbf{u}A\prime}]$ for each $A \in \{\imath, F, Y\}$, $\alpha_{s_m}^{*A} = \alpha_{s_m}^{A} + \alpha_{\imath}^{A} * \gamma_{s_m}$, $\boldsymbol{\beta}^{*\mathbf{o}A} = \boldsymbol{\beta}^{\mathbf{o}\imath} + \boldsymbol{\beta}^{\mathbf{o}A}$, and $\varepsilon_m^{*A} = \alpha_{\imath}^{A} * \mathbf{x_m^u}'\boldsymbol{\beta}^{\mathbf{u}\imath} + \mathbf{x_m^u}'\boldsymbol{\beta}^{\mathbf{u}A} + \varepsilon_m^{A}$ for $A \in \{F, Y\}$. The coefficients $\alpha_{s_m}^{*Y}$ and $\alpha_{s_m}^{*F}$ can be interpreted as the reduced-form effects of a change in organizational structure that include the direct effects of the physical inputs and the indirect effects of changing usage intensity.

The government's utility increases with Y_m and decreases with F_m and dollar costs C_m. It is convenient in the current setting to consider the dual problem of minimizing expected costs given expected levels of mission success and fatalities:

(3) $E\left[C_m|\bar{Y}, \bar{F}, \mathbf{x_m^g}\right] = \min_{s_m, \imath_m} E\left[C_m|\mathbf{x_m^g}\right]$ subject to $E\left[Y_m|\mathbf{x_m^g}\right] \geq \bar{Y}$ and $E\left[F_m|\mathbf{x_m^g}\right] \geq \bar{F}$.

Let $\tilde{C}_m\left(\bar{Y}, \bar{F}, \mathbf{x_m^g}\right)$ denote the minimum expected expenditure required to obtain expected levels $\bar{Y}$ and $\bar{F}$ of success and own fatalities. This cost function is analogous to the cost function in a producer's problem that depends on prices and output. While wages and capital prices do not vary across missions, the vector $\mathbf{x_m^g}$ of correlates of task difficulty serves a similar role as prices. Mission success and fatalities can be viewed as two different products whose output levels enter into the government's objective function. Let P_m and V equal the marginal values to the government of a unit of expected success and a unit reduction in expected fatalities. V is the parameter of interest in this study and is assumed to be constant across missions. The first order conditions of the minimization imply that $P_m = E\left[\frac{\partial \tilde{C}_m(\bar{Y}, \bar{F}, \mathbf{x_m^g})}{\partial \bar{Y}}\right]$ and $V = -E\left[\frac{\partial \tilde{C}_m(\bar{Y}, \bar{F}, \mathbf{x_m^g})}{\partial \bar{F}}\right]$.

As a first approximation, assume that $\tilde{C}_m(.,.,.)$ is linear and can be written as:

(4) $\tilde{C}_m = P_m * E\left[Y_m|\mathbf{x_m^g}\right] - V * E\left[F_m|\mathbf{x_m^g}\right] + \mathbf{x_m^g}'\boldsymbol{\beta}^{\tilde{C}} + \varepsilon_m^{\tilde{C}}$,

where $\boldsymbol{\beta}^{\tilde{C}\prime} = \left[\boldsymbol{\beta}^{\mathbf{o}\tilde{C}\prime} \quad \boldsymbol{\beta}^{\mathbf{u}\tilde{C}\prime}\right]$. Neither $E\left[Y_m|\mathbf{x_m^g}\right]$ nor $E\left[F_m|\mathbf{x_m^g}\right]$ is observed by the researcher; however, substituting Equations (1') and (2') into Equation (4), we obtain:

(4') $\tilde{C}_m = \bar{P} * Y_m - V * F_m + \mathbf{x_m^o}'\boldsymbol{\beta}^{\mathbf{o}\tilde{C}} + \varepsilon_m^{*\tilde{C}}$,

where $\bar{P} = \frac{1}{M}\sum_{m=1}^{M} P_m$ and $\varepsilon_m^{*\tilde{C}} = (P_m - \bar{P}) * Y_m + \mathbf{x_m^u}'\boldsymbol{\beta}^{\mathbf{u}\tilde{C}} + \varepsilon_m^{\tilde{C}} - P_m * \varepsilon_m^Y + V * \varepsilon_m^F$. Notably, we do not allow usage intensity i_m to affect costs directly. This assumption may lead to an upward bias in the estimation of V; however, this bias is probably not very large.[7]

Both Y_m and F_m are endogenous variables that are correlated with components of $\varepsilon_m^{*\tilde{C}}$, such as P_m, ε_m^Y, and ε_m^F. Hence, V cannot be consistently estimated with an Ordinary Least Squares (OLS) regression of Equation (4'). To obtain unbiased estimates of the parameter of interest, we instead use a Two-Stage Least Squares (2SLS) strategy in which Y_m and F_m are endogenous regressors whose values are predicted using Equations (1') and (2') as first-stage regressions with indicators for the different organizational structures as excluded instruments.

In order for the coefficients in Equation (4') to have a structural interpretation, it is essential that organizational structure s_m is a choice variable that is endogenous to the model. Thus, the estimation strategy proposed here uses instruments that are not exogenous. Instead, we impose the weaker assumption of conditional exogeneity that, after controlling for $\mathbf{x_m^o}$, the organizational structure indicators are uncorrelated with unobserved determinants of task difficulty, and P_m, the importance of the mission. Hence, none of the division types can have been used more than others in tasks that were especially difficult in some unobservable way.

The main defense for imposing this assumption is that both the division by day panel and the engagement data include many control variables, among them detailed descriptors of enemy characteristics. Additionally, the sequential nature of the geographic targets limited the degree to which the Army could pick certain division types for certain tasks. While Army doctrine

[7] Higher levels of i_m probably led to higher ammunition costs and capital losses. However, the cost data take into account differences across division types in ammunition usage and tank losses; hence, these cost differences will be reflected in the comparisons across division types. Depreciation of capital other than tanks was a relatively minor cost, making up only 3% and 4% of the costs of the 1942 organic infantry and armored divisions, respectively. Hence, the largest differences in equipment losses among division types are accounted for in the analysis.

recommended using each division type for a specific type of task, the main differences across these tasks were the numbers and types of nearby ally and enemy units, factors that appear in $\mathbf{x}_\mathbf{m}^\mathbf{o}$. Some of the specifications focus on within-division variation in organizational structure and control for U.S. division fixed effects, an approach that provides an even stronger way to control for these doctrine effects. Nevertheless, the need for control variables and the possibility that these controls are incomplete represent important limitations to this study.

One advantage of the 2SLS procedure described here is that it combines the results from multiple margins of adjustment into a single measure of the rate at which the government made tradeoffs between dollars and U.S. fatalities. The procedure also has the unfortunate feature that it lacks transparency. To address this problem, the first-stage and reduced-form regressions are presented in graphical form to illustrate the separate roles of each of the division types in the final estimates, and the 2SLS results are presented separately for different sets of divisions.[8]

Strategy and Endogenous Enemy Characteristics

By including characteristics about enemy units in the set of controls, the model does not allow these characteristics to change based on the U.S. unit's division type or usage intensity. For the division by day panel, this assumption is probably reasonable. That dataset's controls for enemy characteristics are taken from data on long-range movements. Those measures of enemy locations probably responded to large-scale events such as the success of the overall war effort; however, they are too coarse to detect responses to a single U.S. unit's division type.

[8] This 2SLS approach is not intended to explain variation in the dependent variable but instead as a way to combine the various reduced-form coefficients into a summary measure of cost per life saved. In the just identified case in which the sample only includes three division types and only two organizational structure indicators appear in the set of excluded instruments, the 2SLS procedure described here is identical to measuring the effects of a weighted sum of the two policies (*e.g.*, switching from type one to type two and partially switching from type two to type three), where the second policy is implemented in the exact proportion necessary to hold mission accomplishment constant. In this context, V is estimated as the effect of the weighted sum of policies on dollar costs divided by the effect on fatalities. Calculations of this form appear in Rohlfs (2006b) and in the web appendix.

In the engagement data, the controls for enemy characteristics include enemy troops, tanks, aerial sorties, and in some cases, Axis division fixed effects. At the division level, attacking units had the ability to choose their opponents; however, the U.S. was the attacker in 90% of the combat days considered. The primary way in which a defending force could respond is through retreat or withdrawal, actions that are treated as endogenous and are not included in the controls. Hence, for a given engagement, it is not unreasonable to assume that the U.S. treated the German force's starting troop and tank levels as fixed quantities that did not respond to the attacking unit's division type.[9] German troops and tanks may have responded to American organizational structure for the 10% of cases in which the German unit was the attacker, and German air sorties may have responded in the 17% of cases in which there was German air support. Dropping those observations from the sample has little effect on the estimates, as does dropping the Axis inputs from the set of controls (results shown in the web appendix).

In some cases, a unit's actions in one engagement could generate benefits to other engagements. For instance, a U.S. unit's success could reduce the task difficulty for the next Allied unit facing the same enemy. In the current framework, any benefits to other U.S. units are captured in the government's value P_m of the mission. Treating enemy characteristics as pre-determined correlates of task difficulty in $\mathbf{x_m^o}$ helps to avoid double-counting these benefits.

Spillover Effects of Nearby Units

Because multiple divisions usually traveled together as a corps, a given Allied division probably had spillover effects on the geographical progress of other Allied divisions that were nearby. The main specifications address these spillover effects by including the numbers of

[9] Troop and tank levels in the engagement data measure the "feeding strengths" at the start of each engagement. If significant reinforcements arrived, two engagements are defined in the data, one before the reinforcements arrived and one after (Dupuy, 1987, pg. 65).

nearby divisions of different types as control variables in the regressions. Hence, the benefits of the positive spillovers generated by a unit, while valued by the country, are not counted in the mission effectiveness of that unit. An alternative formulation that takes these benefits into account is to model progress as a corps-by-day level phenomenon and to estimate Equation (4') at this higher level of aggregation. Estimates using this approach appear in the web appendix and, while less precise, yield generally similar results to those found in the current study.

Troop and Tank Regressions

One alternative formulation of the first-stage equations that is used in some of the specifications is to replace the organizational structure indicators with continuous regressors measuring the numbers of troops and tanks of the U.S. unit together with their interaction. Implementing this approach involves the following substitutions into Equations (1') and (2'):

$$(5)\ \alpha_{s_m}^{*A} = \alpha_{Troops}^{*A} * Troops_m + \alpha_{Tanks}^{*A} * Tanks_m + \alpha_{TT}^{*A} * Troops_m * Tanks_m,$$

for $A \in \{F, Y\}$. This approach is used for some formulations in the engagement data, for which direct measures exist of U.S. troops and tanks, and it is the one used by Rohlfs (2006a, 2006b). This procedure has the disadvantages that many of the cross-sectional differences in U.S. troops and tanks reflect differences in attachments or detachments (which the Army could change quickly depending on the needs of a given mission) or recent combat losses, increasing the likelihood that the differences are caused by unobserved determinants of difficulty. This approach has the advantage, however, that it can be implemented with U.S. and Axis division fixed effects together with the full set of controls from the engagement data.

V. Empirical Results

This next section presents the main empirical findings from this study. First, estimates from Equations (1’) and (2’) are shown in such a way as to illustrate how the estimated cost per life saved varies across different policies and regression specifications. Due to the large number of pre- and post-reorganization division types and the complex interactions between combat effectiveness and usage intensity, the first-stage regressions of Equations (1’) and (2’) are cumbersome to present in tabular form. For this reason, the first-stage estimates are shown graphically in Figure 3. The corresponding regression tables can be found in the web appendix.

In Figure 3, the variables that we treat as exogenous are division type (Armored, Infantry, or Airborne) and pre-post reorganization. The combination of these two variables sorts the data into six or fewer distinct groups, depending upon data availability, which varies across the graphs shown. Each of these unit types had a certain cost, experienced a certain rate of fatalities, and achieved a certain level of mission accomplishment. These levels vary by model, which explains the existence of the eight different graphs.

The axes of the graphs show only two dimensions, cost and fatalities, and those variables are plotted along the vertical and horizontal axes, respectively. In order to illustrate the third dimension, mission success, in a way that is easily identifiable for readers, we plot the dashed isoquant curves that are shown. The curves are hand-drawn --i.e., they are not the result of an estimation process --and they are generated to be consistent with the ordering of the mission accomplishment levels achieved by the different unit types shown on the graph. Each of the resulting curves is the simplest, smoothest one that we could draw given the ordering of mission accomplishment levels observed in the data across those six or fewer points. Within each of the eight panels in Figure 3, the estimated dollar cost of a 10.8-month deployment of that division type is shown on the vertical axis. These cost estimates are the same as appear in Figure 1. The

ETO costs are used in panels A through D and G and H.[10] The costs for the actual troop and tank levels are used in panels E and F and are the same as those that appear in Figure 1. The number of fatalities that the division would be estimated to incur over that 10.8 months is shown on the horizontal axis. The average levels of mission success as shown in the isoquants are calculated as predicted values by division type from Equation (1'), where the control variables are set equal to the averages over the sample being used. The isoquants show alternative combinations of dollar costs and U.S. fatalities that generate equivalent levels of mission effectiveness. Division types on the upper left of the graph were expensive in dollars but experienced few fatalities. Moving downward and to the right along an isoquant, the dollar cost of the unit decreases. In order to maintain the same level of effectiveness, usage intensity increases, leading to higher numbers of fatalities. The slope of this curve is an estimate of the rate of tradeoff between expenditures and fatalities. In some cases, the curves could be steeper or flatter and still agree with the observed levels of success; however, the range of possible slopes is fairly narrow at many key points on the graphs.

While the slopes of these isoquants are not the result of a formal estimation process, the placement of the different points in terms of cost, fatalities, and mission accomplishment is surprisingly restrictive in terms of what the isoquants might look like. In panels A, B, and C, for instance, any isoquant that is consistent with the data must have a steep portion in the upper left part of the graph (to match the ordering of the two black points) and a flat portion in the lower right-hand part (to match the ordering of the two gray points).

[10] The cost for pre-reorganization infantry, which is missing in Figure 1, is estimated for these data by assuming that the percentage change in costs generated by the infantry reorganization was the same as in the engagement data. Additional information on the ETO costs presented in Figure 3 is included in the web appendix.

Fatalities are estimated by first computing predicted values from Equation (2'), where U.S. KIA is the dependent variable and the control variables are set to their sample averages. For the regressions using the division by day panel, total KIA for a 10.8-month deployment is estimated by multiplying predicted KIA per combat day by the average division's number of combat days and dividing by the fraction of U.S. KIA that occurred on those combat days. To convert from KIA to fatalities, the 10.8-month KIA totals are divided by 0.84, the fraction of U.S. deaths that were KIA. Hence, a division type's fatalities over the deployment are assumed to be proportional to KIA for that division type on an average combat day.

Panels A through D show results from the division by day data; panels A and B use the sample of division days with nearby Axis divisions, and panels C and D use the sample of division days with five or more U.S. KIA. Panels E through H show results from the engagement data. In panels G and H, the averages by division type are estimated using the coefficients from the troop and tank regressions and plugging in the average troop and tank numbers from the ETO data. The measure of mission success is km progress in panels A through D and the index of mission accomplishment in panels E through H. In panels A, C, E, and G, no control variables are used. Hence, for panels A, C, and E, the fatalities estimates are scaled versions of the KIA averages shown in Figures 1 and 2, and the mission effectiveness estimates used to generate the dashed lines are taken from those same figures. Panels B and D show conditional means estimated from regressions that control for date and continent, numbers of nearby Allied and Axis divisions, terrain, vegetation, weather, and combat experience; panels F and H control for date and continent, U.S. aerial sorties, enemy inputs, terrain, vegetation, weather, and human factors. These controls are listed in the footnotes to Tables 1 and 2.

When the data are sufficiently informative in Figure 3 to determine the cost per life saved, as measured by the slope of the isoquant, it tends to be highest at the higher cost levels, with a generally steeper tradeoff than the efficient rate of one to two million dollars per life. At the lower cost levels, the cost per life saved tends to be lowest and flatter than this efficient rate. In each of panels A, C, and E, dollar costs are highest for the armored divisions, and fatalities are highest for the airborne divisions. The isoquants are roughly convex in all three panels, with kinks around the middle expenditure levels in panels A and E and a backward-bending portion for the armored divisions in panel C. At the highest two cost levels in panel A, the average slope between the cost levels of the pre- and post-reorganization armored divisions on the highest isoquant is about –$3 million per life. On the same isoquant in panel A, the slope between the lowest cost levels of the pre- and post-reorganization airborne divisions is about –$0.5 million per life. On the highest isoquant drawn on panel C, the slope between the cost levels of the pre- and post-reorganization armored divisions is roughly +$2 million per life. The curve flattens to about –$1 million per life between the cost level of the post-reorganization armored and the fatality level of the infantry division. While the slope is unclear at lower cost levels, the curve is necessarily flatter than the roughly –$0.9 million per life slope between the infantry divisions and the post-reorganization airborne division, which is on a lower isoquant. On the highest isoquant in panel E, the average slope between the cost level of the pre-reorganization armored division and the fatality level of the post-reorganization airborne division is about –$0.7 million per life. When the troop and tank regressions are used in panel G, many slopes are possible, and the data are fairly uninformative about the tradeoffs between expenditures and U.S. fatalities.

When controls are added to the regression for the sample with nearby Axis divisions in panel B, the slope steepens. On the second-highest isoquant in panel B, the average slope

between the cost levels of the pre- and post-reorganization armored divisions is about –\$6 million per life. On the highest isoquant in panel B, the average slope between the fatality levels of the pre-reorganization armored and the post-reorganization airborne divisions is about –\$1 million per life. For the sample of division days with five or more U.S. KIA, adding controls in panel D generates isoquants that are not consistent with a government that values mission success. When controls are added to the engagement data in panels F and H, we observe relatively flat slopes. In panels F and H, the slopes of the isoquants between the fatality levels of the pre-reorganization armored and the pre-reorganization infantry divisions are not explicitly determined but are necessarily less than –\$0.4 million and –\$0.6 million per life, respectively.

The remainder of this section presents 2SLS estimates of $\bar{P}$ and V from Equation (4'). Table 1 shows the 2SLS results for the division by day panel. Within each panel, each column shows results from a separate 2SLS regression of Equation (4'), where the dependent variable is cost per combat day, the endogenous regressors are geographic progress and U.S. fatalities, and the excluded instruments are indicators for the different pre- and post-reorganization division types. To construct daily fatalities, U.S. KIA are divided by the product of the fraction of U.S. KIA that occurred on combat days times the fraction of U.S. fatalities that were KIA. The coefficient on progress can be interpreted as the U.S. government's valuation of one km of progress in a typical combat day, and the coefficient on U.S. fatalities can be interpreted as negative one times the U.S. government's valuation of a unit reduction in fatalities.

In panel A of Table 1, the sample includes division days in which the U.S. division was in the same cell as one or more Axis divisions; in panel B, the sample includes division days in which U.S. KIA was five or greater. The first three columns show results from the full sample of combat days, and columns (4) and (5) present results from the fixed effects samples. Column (1)

shows results controlling for a time trend and continent fixed effects. Column (2) includes the full set of controls, and columns (3) and (4) add fixed effects for month x year, nearby Axis divisions, and 0.25 x 0.25-coordinate geographic cells. Relative to Figure 3, the regressions in columns (1) to (4) impose a constant slope on the isoquants and constant growth in mission effectiveness per dollar of expenditure from one isoquant to another. The regressions in column (5) control for U.S. division fixed effects, so that the indicators for armored and airborne appear in the controls and the coefficients of interest are identified from variation generated by the reorganizations. The remaining columns of Table 1 apply varying restrictions to the sample so that the coefficients of interest are identified from different combinations of the instruments. In each case, the controls are included in the first column, and month x year, Axis division, and cell fixed effects are added in the second column. Standard errors clustered by U.S. division by year by month interaction are shown in parentheses.[11] These standard errors do not take into account imprecision in the construction of the dollar cost measure.

In columns (1) to (4), the coefficients on km progress in both panels are unstable and change signs across specifications. Hence, we do not find a consistent positive marginal cost of increasing mission success, possibly due to the combined imprecision of the progress measure and the linear specification. The U.S. fatality coefficients in columns (1), (2), (3), and (4) in panel A are -1.436, -1.926, -0.476, and -0.408, respectively. All four of these coefficients are statistically significant at the five percent level. This is in contrast to the first four columns in panel B, where only the U.S. fatality coefficient in column (3) is marginally significant. The U.S. fatality coefficients in columns (1), (2), (3), and (4) in panel B are -0.711, -4.673, -2.521, and -3.197, respectively. Thus, the marginal cost per life saved estimates in columns (1) to (4) in

[11] Some autocorrelation probably exists between divisions and between days from different months. The smaller clusters are used so that the model is estimable with the full set of controls and fixed effects. When fewer covariates are used, using fewer clusters in both datasets has little effect on the standard errors, as shown in the web appendix.

panels A and B range in value from $0.41 million to $2.5 million, with average and median estimates of $1.9 million and $1.7 million per life. The larger estimates are from regressions with negative coefficients on km progress, a result which suggests that the regressions with the higher cost per life saved do not adequately control for the mission effectiveness of the unit.

When U.S. division fixed effects are included in the regressions in column (5), the coefficient on progress is positive in panel A and zero in panel B, and the estimated costs per life saved are $0.3 million and $0.4 million. When the sample restrictions are applied in columns (6) to (15), the coefficient on U.S. fatalities is negative in 18, significant in four, and marginally significant in three of the 20 specifications. The estimated cost per life saved tends to be larger in panel B, with average and median values of $2.8 million and $1.3 million than in panel A, with average and median values of $1.3 million and $1.2 million. The coefficient on km progress tends to be positive in the sample with nearby Axis divisions in panel A and negative in the sample with five or more U.S. KIA in panel B; hence, the larger estimated cost per life saved in panel B is probably attributable to the regressions failing to adequately control for the policies' effects on mission accomplishment. When considering tradeoffs between armored and either of the other two division types, the cost per life saved estimates in panel A range from $0.5 million to $1.5 million. The estimated cost per life saved is considerably lower, ranging from zero to $0.3 million, when the sample is restricted to infantry and airborne divisions, and the coefficient on km progress is negative in three out of four of those specifications. In columns (12) to (15), we find comparable cost per life saved estimates pre- and post-reorganization. The cost per life saved estimates are also generally smaller in the specifications that include the month by year, Axis division, and geographic cell fixed effects.

Table 2 shows 2SLS estimates of Equation (4') from the engagement data. In panel A, mission success is measured as km of progress along the attacker's axis of advance, and in panel B, mission success is measured using the subjective index. Within each panel, each column shows results from a different regression. In columns (1) through (5), the sample excludes the airborne observations, and the excluded instruments are three indicators for division type (armored, post-reorganization times armored, and post-reorganization times infantry).[12] In columns (6) to (15), the excluded instruments are U.S. troops, U.S. tanks, and their interaction.

The coefficient on mission effectiveness is more consistently positive in Table 2 than in Table 1, probably due to the greater precision of the effectiveness measures in the engagement data. The specifications that use the success index in panel B have the most consistently positive and precisely estimated coefficients on mission effectiveness, a result that suggests that these specifications more effectively control for mission success than do the ones in panel A. The coefficient on the success index is positive in 14, significant in six, and marginally significant in three of the specifications. The coefficient on km progress tends to be larger in Table 2 than in Table 1, because the engagement sample includes fewer combat days and unlike U.S. fatalities, the mission success measures are not scaled upward to count progress made on non-combat days. Among the specifications using division type as the excluded instruments in columns (1) to (5), the coefficient on U.S. fatalities is positive in the two specifications without controls and is negative in the remaining eight specifications. Among the specifications with controls, the cost per life saved estimates range from \$0.2 million to \$1.9 million, and the specifications with all of the controls produce significant estimates of \$0.4 million to \$0.6 million per life saved.

[12] The ten combat days of the 101st Airborne Division in Bastogne in December 1944 are dropped from this sample due to high numbers of attached troops and tanks that made them unrepresentative of a typical airborne organization.

When U.S. troops and tanks and their interaction are used as instruments in columns (6) to (15), the specifications are also sensitive to the inclusion of controls. When controls are included and when km progress is used as the measure of success in panel A, we obtain a small positive coefficient on U.S. fatalities in the sample with low tank-intensity and negative coefficients on U.S. fatalities in the full sample and in the sample with high-tank intensity; however, the specifications with negative coefficients on U.S. fatalities also produce negative coefficients for km progress, suggesting that these specifications do not adequately control for mission effectiveness. In the corresponding specifications in panel B, we observe a consistently positive coefficient on mission success and estimated costs per life saved of $1.2 million for the full sample, –$0.1 million for the low tank intensity sample, and $0.4 million for the high tank intensity sample (which includes some units around the tank-intensity level of the infantry division), results that are generally consistent with those found in panel A of Table 1. Similar results are found for the fixed effects sample as for the full sample; however, the results become too imprecise to make inferences when fixed effects are added to the regressions in columns (14) and (15).

After taking into account placing value on soldiers' lives, our estimates suggest that the U.S. government appeared to value armored troops' lives more than those of infantry troops. Thus, this discrepancy existed initially, but then they regarded that decision as a mistake and reorganized the divisions in 1943. That reorganization largely corrected the discrepancy in the valuation of soldiers' lives between the two types of units. An additional explanation for the difference in these estimates is that soldiers in armored divisions had more human capital than did soldiers in infantry divisions. While some of that difference is accounted for by differences in training expenditures, which we measure, other differences are accounted for by soldiers in

armored divisions having more experience and higher quality experience than infantry soldiers do.

VI. Conclusion

Our study examines tradeoffs that the U.S. government made between different types of military units so as to save soldiers' lives in WWII. Multiple data sources are used to measure physical inputs, fatalities, geographical characteristics, and dollar expenditures of each unit, including new data compiled from archival sources on the experiences of all 67 U.S. divisions that fought on the Western Front. We examine the effects of substitution among three different types of units –armored, infantry, and airborne divisions—as well as the effects of mid-war reorganizations of each unit type. A conceptual framework is developed to understand the interactions between the physical inputs of the unit, the intensity with which the unit is used, and the difficulty of tasks to which it is assigned, and a procedure is derived for estimating the marginal cost of reducing U.S. fatalities through an increase in tank intensity. Assuming that the U.S. government was a rational actor who equated marginal costs and marginal benefits, this cost provides a measure of the implicit value that the government placed on reducing American military deaths.

While variable across specifications, the results of this study indicate that, at moderate tank-intensity levels such as that of the infantry division, the cost per life saved from an increase in tank intensity for a deployment with average usage and task difficulty was roughly zero to $0.5 million in 2009 dollars. This range falls below Costa and Kahn's (2004) $1 million to $2 million estimates of the private valuation of risk reductions among young men in the 1940s. At relatively high tank-intensity levels such as that of the armored division, the cost per life saved

from an increase in tank intensity was roughly $2 million to $6 million or more in 2009 dollars. Thus, our results suggest that the U.S. government implicitly undervalued infantrymen's lives and slightly overvalued armored personnel's lives relative to the private value of citizens at the time. Both the 1943 reorganization of the armored division, which greatly reduced costs and slightly increased fatalities, and the 1944 reorganization of the airborne division, which greatly reduced fatalities and increased costs slightly, are found to have increased economic efficiency.

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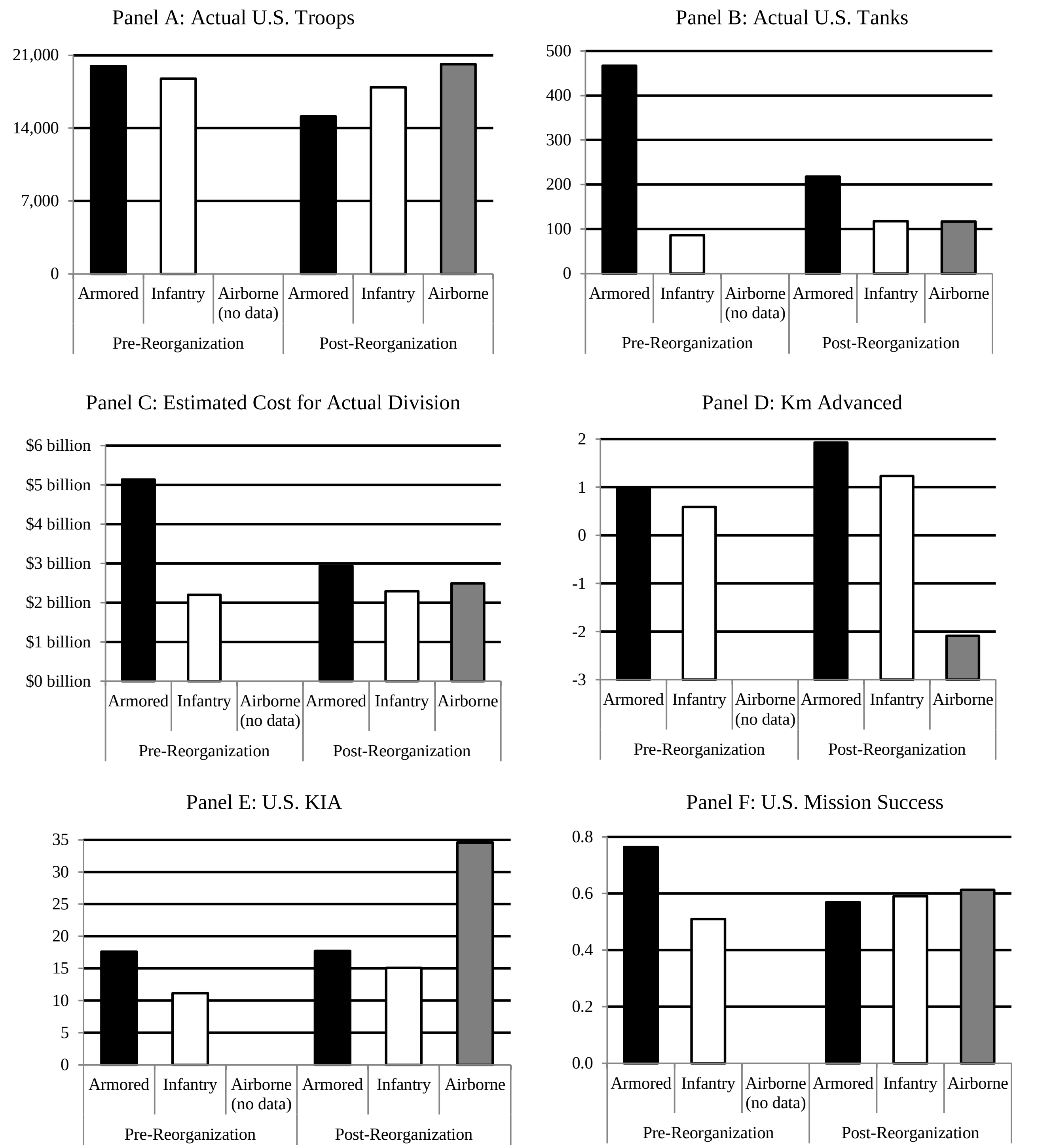
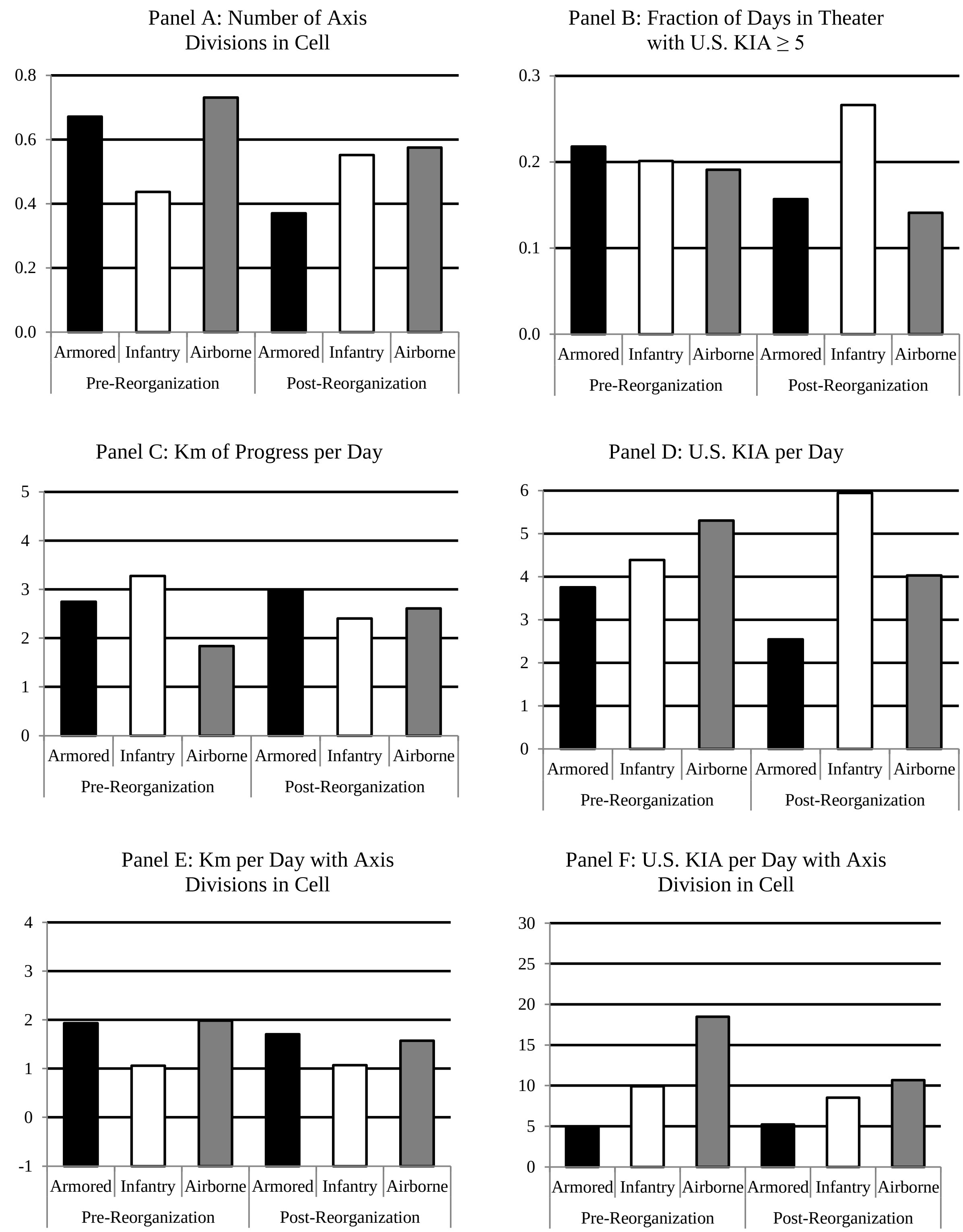
Figure 1: U.S. Troops, Tanks, Estimated Cost, and Combat Outcomes by Division Type (Engagement Data)



Notes to Figure 1: Actual troops and tanks are taken from primary sources such as morning roll call counts. Costs measured as $92,400 per troop, $5.84 million per tank, and an additional $1.63 million per tank used in an armored division due to armored divisions' higher rates of tank losses. Estimated costs are in 2009 U.S. dollars. Mission success is measured as a zero to one index. Full sample is used and additional details are available in the appendix.

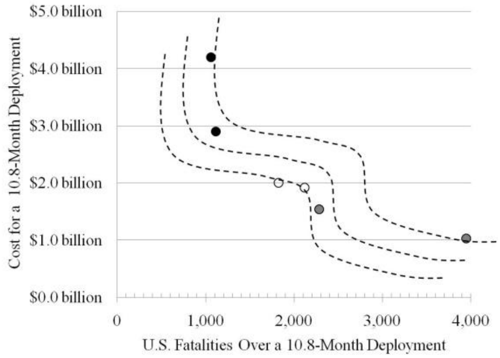
Figure 2: Combat Outcomes and Usage in Combat by Division Type (Division by Day Panel)



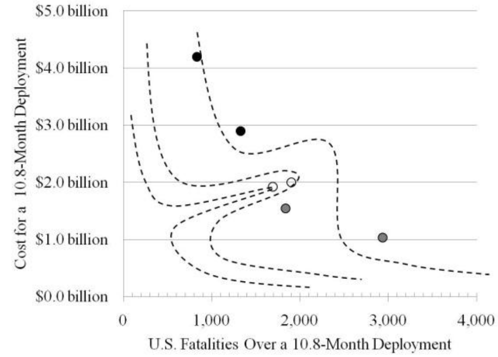
Notes to Figure 2: Data and variables are defined in the same way as in Table A1. Panels E and F show U.S. km of progress per day and U.S. KIA, respectively when the sample is restricted to observations in which one or more Axis divisions is in the same cell as the U.S. division.

Figure 3: Estimated Costs, Fatalities, and Military Production Isoquants by Division Type

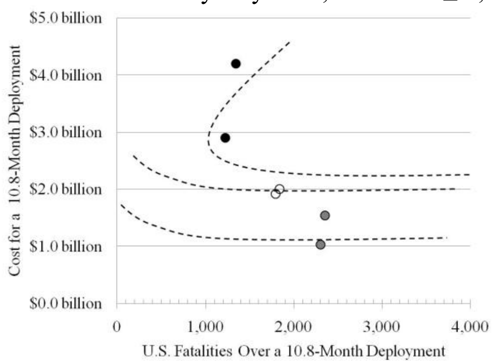
Panel A: Division by Day Data, Axis in Cell, No Controls



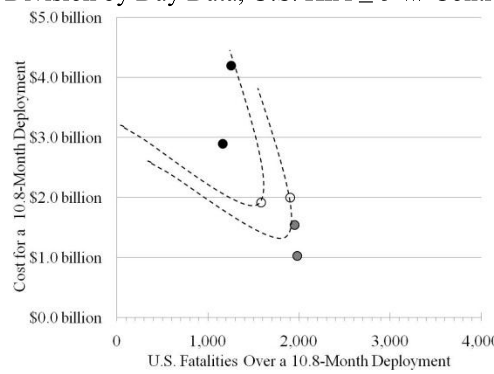
Panel B: Division by Day Data, Axis in Cell w/ Controls



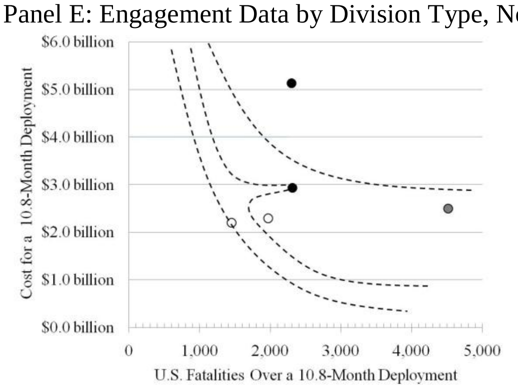
Panel C: Division by Day Data, U.S. KIA ≥ 5, No Controls



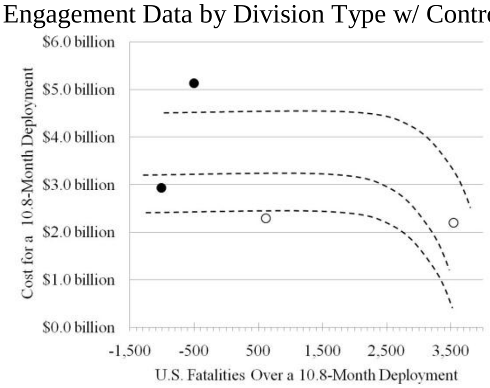
Panel D: Division by Day Data, U.S. KIA ≥ 5 w/ Controls



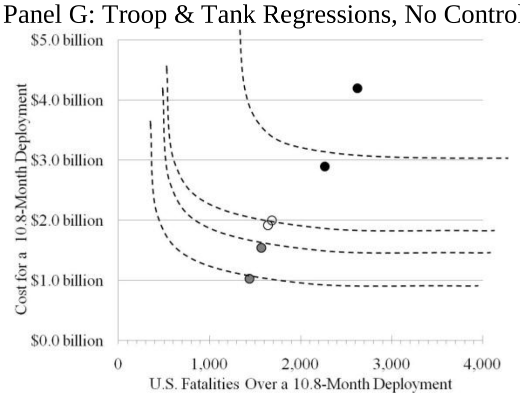
Panel E: Engagement Data by Division Type, No Controls



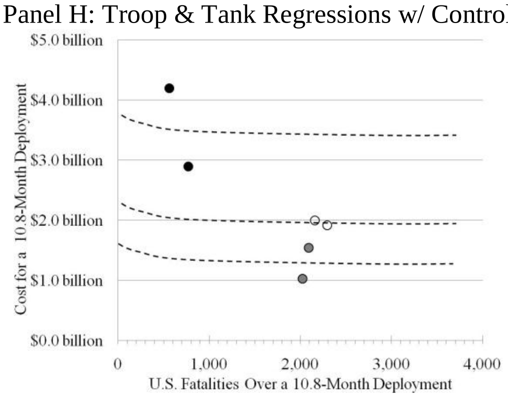
Panel F: Engagement Data by Division Type w/ Controls



Panel G: Troop & Tank Regressions, No Controls



Panel H: Troop & Tank Regressions w/ Controls



Notes to Figure 3: In each panel, the points show estimated costs and fatalities for a given division type over a 10.8-month deployment, assuming average usage. The black dots correspond to armored divisions, the white dots correspond to infantry divisions, and the gray dots correspond to airborne divisions; both pre- and post-reorganization means are shown. The dashed curves show hand-drawn isoquants for military effectiveness that are consistent with the estimated levels of effectiveness of each division type. Effectiveness is measured in panels A to D as km advanced while engaged and in E to H with the index. All controls specifications include the full set of controls.

Table 1: 2SLS Estimates of the Cost Function for Military Operations, Division by Day Panel

Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
	Dependent Variable is Estimated Dollar Cost per Day in Millions of 2009 Dollars														
	Panel A: Division Days in Which Axis Divisions in Cell ≥ 1														
	Full Sample			Fixed Effects Sample		Only Armored and Infantry		Only Infantry and Airborne		Only Armored and Airborne		Only Pre-Reorganization		Only Post-Reorganization	
Km of	2.093	-0.288	5.670	-2.993	2.997	8.408	6.507	-15.06	-9.403	8.207	1.127	0.423	1.656	-27.69	0.247
Progress	(12.20)	(9.057)	(3.084)*	(3.519)	(3.763)	(9.157)	(5.645)	(21.01)	(6.227)	(10.50)	(1.518)	(4.939)	(22.18)	(128.7)	(6.047)
U.S.	-1.436	-1.926	-0.476	-0.408	-0.332	-1.428	-0.524	0.048	-0.126	-1.475	-0.888	-1.637	-1.444	-4.371	-0.854
Fatalities	(0.583)**	(0.625)**	(0.177)**	(0.194)**	(0.387)	(0.768)*	(0.354)*	(2.464)	(0.183)	(0.615)**	(0.261)**	(0.576)**	(2.361)	(12.31)	(0.658)
R^2	-71.78	-114.1	-22.92	-4.330	-2.525	-110.9	-28.34	-3,003	-722.2	-65.24	-6.868	-13.28	-5.103	-4,062	-11,997
N (Division Days)		4,430		1,137		4,107		3,689		1,064		598		3,832	
Clusters (Division Months)		470		115		441		371		128		66		407	
	Panel B: Division Days in Which U.S. KIA ≥ 5														
Km of	6.955	-18.58	-17.82	-0.996	0.019	-80.49	-13.85	7.891	-5.597	33.66	1.554	-0.846	-7.023	-22.39	-15.57
Progress	(7.509)	(27.46)	(14.28)	(5.292)	(0.216)	(338.1)	(12.37)	(8.692)	(3.834)	(94.89)	(4.155)	(11.65)	(5.130)	(95.47)	(23.00)
U.S.	-0.711	-4.673	-2.521	-3.197	-0.371	-14.48	-2.292	-0.014	-0.295	2.068	-1.502	-4.956	-0.455	-4.849	-1.180
Fatalities	(1.202)	(4.587)	(1.295)*	(3.276)	(0.837)	(53.23)	(1.025)**	(1.141)	(0.229)	(10.44)	(0.893)*	(5.268)	(0.978)	(15.15)	(1.102)
R^2	-80.23	-766.6	-267.1	-86.5	-0.160	-11,997	-170.8	-1,940	-560	-981.4	-5.956	-42.24	-3.185	-3,140	-768.4
Controls?		Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Month & Year FEs			Yes	Yes	Yes		Yes		Yes		Yes		Yes		Yes
Axis Division FEs			Yes	Yes	Yes		Yes		Yes		Yes		Yes		Yes
Cell FEs			Yes	Yes	Yes		Yes		Yes		Yes		Yes		Yes
U.S. Division FEs					Yes										
N (Division Days)		4,579		1,221		4,395		3,841		922		621		3,958	
Clusters (Division Months)		516		137		488		407		137		82		436	

Notes to Table 1: Standard errors clustered by division x year x month interaction. Variables and data are the same as in Table A1. All specifications control for continent dummies and a daily time trend. Continent dummies include North Africa, Sicily, Italy, and Northwest Europe. Additional controls include numbers of German, Italian, Panzer, Axis SS or Parachute, U.S., non-U.S. Allied, and Allied armored divisions in the same cell and numbers in neighboring cells, degrees slope, monthly wet days, precipitation, and mean temperature, dummies for slope > 5 degrees, wet or rainy, wooded or mixed vegetation, and cultivated land, prior days in theater, prior days with U.S. KIA ≥5, and days in the past 30 days with U.S. KIA ≥5. Wet or rainy indicates whether wet days exceeded 20 or precipitation exceeded 125 mm for that cell in that month. ** indicates 5% significance; * indicates 10% significance.

Table 2: 2SLS Estimates of the Cost Function for Military Operations, Engagement Data

Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
	Dependent Variable is Estimated Cost per Day in Millions of 2009 Dollars														
	Panel A: Mission Effectiveness Measured as Km Progress														
	Excluded Instruments are Indicators for Armored, Post-Reorganization*Infantry, and Post-Reorganization*Armored					Excluded Instruments are U.S. Troops, U.S. Tanks, and U.S. Troops * U.S. Tanks									
	Excluding Airborne					Full Sample		Low Tank Intensity		High Tank Intensity		Fixed Effects Sample			
Km of Progress	-1,411	558.1	-721.6	21.73	74.22	48.58	-338.8	279.6	47.06	1,051	-365.0	-961.2	89.28	274.6	227.6
	(3,449)	(594.2)	(1,425)	(58.19)	(68.44)	(1,220)	(361.6)	(127.9)**	(27.39)*	(2,009)	(260.9)	(2,265)	(91.69)	(219.3)	(306.0)
U.S. Fatalities	3.838	-1.244	-0.889	-0.120	-0.386	7.049	-3.344	0.427	0.195	10.364	-2.252	7.057	-1.080	-0.880	1.380
	(13.61)	(1.414)	(1.833)	(0.178)	(0.170)**	(7.808)	(2.904)	(1.006)	(0.099)*	(17.58)	(1.794)	(12.463)	(0.662)	(0.670)	(1.775)
R^2	-278.9	-36.93	-55.44	0.182	-0.105	-178.4	-26.88	-24.9	0.644	-491.6	-14.63	-486.1	-3.292	-12.31	-4.456
	Panel B: Mission Effectiveness Measured with Zero to One Index														
Index of Success	2,995	-760.4	2,296	4,053	2,578	578.0	3,064	5,487	727.0	7,194	4,612	13,757	4,295	41,343	5,847
	(872.7)**	(2,570)	(925.9)**	(1,562)**	(753.8)**	(13,561)	(1,571)**	(10,558)	(343.5)**	(4,246)*	(2,353)*	(9,711)	(2,565)*	(188,230)	(17,217)
U.S. Fatalities	0.630	-1.896	-0.461	-0.212	-0.626	6.727	-1.227	-2.191	0.100	-0.052	-0.394	-2.247	-1.584	6.793	-2.517
	(1.251)	(1.696)	(0.592)	(0.379)	(0.202)**	(12.12)	(0.783)	(4.114)	(0.112)	(1.823)	(0.407)	(3.879)	(1.199)	(35.59)	(8.368)
Controls Include . . .															
Date & Continent	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Sorties & Enemy Inputs		Yes			Yes		Yes		Yes		Yes		Yes		Yes
Terrain & Weather			Yes		Yes		Yes		Yes		Yes		Yes		Yes
Human Factors				Yes	Yes		Yes		Yes		Yes		Yes		Yes
Axis Division FEs														Yes	Yes
U.S. Division FEs														Yes	Yes
R^2	-4.094	-10.64	-2.070	-3.443	-1.001	-163.7	-3.980	-69.54	0.596	-15.08	-1.497	-126.5	-10.79	-557.4	-18.59
N (Division Days)			279			289		150		139		225			
Clusters (Engagements)			152			162		75		87		132			

Notes to Table 2: Sortie and enemy input controls include U.S. and German aerial sorties, and German troops, tanks, and their interaction. Terrain, weather, and vegetation controls include dummies for mountain or river, rugged terrain, wet or rainy, temperate, wooded or mixed vegetation, and urban or con-urban. Human factor controls include an indicator for whether the U.S. was the attacking force and indices for leadership, training and force quality, intelligence and planning, logistics and reserves, morale, surprise, and defensive fortifications. Low and high tank intensity are defined relative to the median. Standard errors adjust for clustering by engagement.

Data Appendix

Division by Day Panel

This study introduces to the literature a new dataset describing the experiences of every U.S. Army ground division on the Western Front from November 1942 through May 1945. The sources and calculations for these data are described in detail in the web appendix. Fatalities are measured using division-specific casualty rosters that include name, serial number, battalion or regiment, rank, military occupation, and type of death (killed in action, died of wounds, or finding of death) for every battle-related fatality for each division. The rosters only include deaths to the organic division and do not include deaths to attached units. These rosters were copied from archival records and sent to an Indian company to be hand-entered. For all of the variables except name, the data were entered a second time by us, with all discrepancies corrected. The date of death was hand-written on the original records for a randomly-selected 39% of the cases. To obtain more complete information on date of death, these data were merged with four other casualty lists obtained from various sources. Some of the airborne divisions traveled with large, permanently-attached infantry regiments; these regiments' fatalities are added to the data from separate online casualty rosters. The resulting dataset includes 144,534 deaths, including 119,117 from the Western Front; date of death is observed for 69% of the cases. The data are summed up by division, date, and type of death. To adjust for missing dates, these sums are divided by the division-specific fraction of cases with non-missing dates.

Data on the locations of all the 183 Allied and 285 Axis divisions that were on the Western Front were transcribed from multiple secondary sources by a team of research assistants and us. For the average U.S. division, the location is identified for 23 separate dates. The average non-U.S. Allied division's location is identified for eight separate dates, and the average

Axis division's location is identified for 18 separate dates. Locations for between dates are imputed by assuming that each division traveled in a straight line at a constant speed. Locations were not recorded for units that were smaller than divisions, such as battalions and brigades. Non-divisional combat troops constituted about 1/3 of the U.S. Army ground combat troops on the Western Front (Greenfield, Palmer, and Wiley, 1947, pg. 194); usage of non-divisional units appears to have been about as common in other countries' armies. While these non-divisional elements' locations are not measured directly, they tended in both the Allied and Axis armies to be attached to divisions or corps (Axis History Factbook, 2009; Haskew, 2009). Hence, the divisions' locations provide approximate measures of where troops were concentrated.

The data on U.S. division locations determine the set of observations in the final division by day panel. Division days in which the unit was at sea are dropped from the sample, as are division days from North Africa after the end of fighting in that theater in May 1943. One of the infantry divisions, the 10^{th} Mountain Division, had a unique organizational structure and set of tasks and included many experienced mountaineers and famous athletes (Kahn and McLemore, 1980, pg. 20; Wilson, 1998, pp. 188-90); this unit is dropped from the sample.

For each division day, the location data are used to obtain information on terrain and historical vegetation and weather. High-resolution elevation data are used in ArcGIS to compute the slope, a measure of the steepness of the terrain. Additionally, ArcGIS is used to compute the land distance from each point to the nearest of five port cities (Cherbourg, Messina, Pampelonne (near Marseille), Salerno, and Tunis) and the land distance to the "target," which is identified as Tunis, Messina (in Sicily), or Berlin, depending on the continent. The slope and distance variables are averaged over the 0.25 x 0.25-coordinate cell in which the division is estimated to reside. These cell averages are used to create one of the key measures of mission effectiveness

in this study, kilometers (km) of progress, which is estimated as the decrease from the previous day in land distance from Berlin, Tunis, or Messina. Km of progress is set to zero for the day when a unit first landed on a continent. Monthly historical data on weather from 1942 to 1945 and vegetation data from 1950 are obtained at the level of the 0.5 x 0.5-coordinate cell. The data also include two measures of the division's combat experience – the number of prior days in the theater and the number of prior days with five or more U.S. KIA.

Table A1 presents means and their standard errors for the key variables in the division by day panel. Column (1) shows statistics for all 19,721 division days. Columns (2) and (4) use two different approaches for dropping non-combat days of unimpeded movement from the data. In column (2), the sample is restricted to division days in which the division's 0.25 x 0.25-coordinate cell is estimated to have been shared with one or more Axis divisions. In column (4), the sample is restricted to division days with five or more U.S. KIA. The fixed effects samples shown in columns (3) and (5) further restrict the data to the eight divisions (one armored, six infantry, and one airborne) that were reorganized while in the theater and experienced combat both before and after the reorganizations. Column (6) explores the representativeness of the engagement data by restricting the sample to the 289 division days that appear in that dataset.

On the average division day in the full sample, the division made 2.61 km of progress toward its target, experienced 5.02 KIA, and shared its cell with 0.889 other Allied divisions and 0.521 other Axis divisions. When non-combat days are dropped from the sample in columns (2) and (4), we see slower rates of progress of 1.23 and 2.06 km per day, and we see higher U.S. KIA per day of 8.25 and 19.4. The numbers of Allied and Axis divisions in the same cell are also larger for combat days, at 1.58 and 2.32 in column (2) and 1.25 and 0.890 in column (4). The two methods for dropping non-combat days have different effects on the sample. Progress is

slower in the sample in column (2) in which Axis divisions were present (and the tasks were relatively difficult), and U.S. KIA are higher in the sample in column (4) in which U.S. KIA were five or greater (and combat was relatively intense). Relative to columns (2) and (4), progress is slower in the fixed effects samples in columns (3) and (5), possibly due to their lower fractions of armored divisions. Progress, U.S. KIA, and the numbers of nearby Axis divisions are similar between the days from the engagement sample in column (6) and the days with five or more U.S. KIA in column (4). The other control variables differ some across the various samples. The fraction of days below freezing is higher in the sample with Axis divisions in the same cell. In the fixed effects samples, the combat occurred earlier, more of it happened in North Africa and Italy, and combat experience is higher. The days from the engagement data also occurred earlier and on steeper terrain, and more of them occurred in Italy.

Engagement Data

The engagement data used in this analysis come from the *Division-Level Engagement Database* (DLEDB). These data are proprietary and may be acquired at a cost from The Dupuy Institute. The DLEDB includes engagements from multiple wars; however, the current study only uses the 162 engagements that were fought over 289 days between U.S. and German forces during WWII. The DLEDB is not a representative sample, and The Dupuy Institute generally collected data on engagements that were particularly large or well-documented. The dataset is described in more detail in The Dupuy Institute (2001b, 2005). The key measures of mission effectiveness used from this dataset are km of progress and a subjective index of success, a measure that takes into account multiple factors including geographical progress and target destruction.

In regards to the background information on how the data was compiled, each observation (engagement) in the data was measured by going to Archives II in College Park, MD and reading through unit historical records. The researcher would sort through the U.S. and German Archives to obtain information on both sides of the conflict and write down numbers of troops (usually based off of morning roll calls), numbers of vehicles, weather, terrain, specific locations on different days, all based upon the unit's records. The same researcher would use these variables to form judgments on a number of components of mission accomplishment, which are the components of the worksheet included in Figure A1. That worksheet shows how to go from subjective judgments to a final number, which we converted into a zero-to-one index.

As the figure shows, each unit is scored on five criteria. The first three criteria relate to specific mission objectives. These include conceptual accomplishment (a general evaluation of achievement of mission objectives), geographical accomplishment (i.e., miles advanced), and block hostile mission. Together, these objective-based scores can range from zero to six. In addition to these three objective-based measures, the index incorporates general evaluations of the performance of officers and enlisted men. Together these general evaluations can range from zero to four points.

In principle, each side's mission accomplishment can be evaluated separately and ranges from zero to 10. In practice, attacker and defender mission accomplishment are nearly perfectly negatively correlated. Mission accomplishment ratings do not exceed nine for either side for the 164 engagements used in our analysis. The subjective index of mission accomplishment used in this paper is (U.S. total score – German total score)/16. We decided to divide by 16, because that was the range of values seen in the data, and then we added 0.5. Of note, dividing by 20 would have the same effect except that the value would just be a little more compressed. A value of

zero in the index indicates that the mission for the U.S. unit was a complete disaster. In contrast, a value of one suggests the mission was a total success. A value of 0.5 could be viewed as being roughly a draw between the two sides in terms of mission accomplishment.

One limitation of this subjective mission accomplishment measure is that it assigns equal weight to each of the five criteria. Ideally, it would be possible to vary the weights for these criteria depending on their relative importance in different missions. Another limitation of this subjective mission accomplishment measure is the emphasis on troops. Command and staff performance and troop performance are both rated separately from accomplishment of specific objectives. No such rating exists, however, for the performance of capital. Hence, this subjective measure may be overly sensitive to the use of troops in combat.

The mission effectiveness and enemy force size measures are particularly useful because, unlike the corresponding variables in the division by day panel, they are observed firsthand and do not require imputation. The KIA data have the desirable feature that they include deaths to attached units and not just to the organic division. Data for German KIA are missing for 74 of the 289 division days, and data for U.S. KIA are missing for 53 of the 289 division days. In all of these cases, data are available on total casualties, which include KIA, WIA, and MIA. The missing KIA values are imputed by calculating the ratio of KIA to total casualties among the non-missing observations for that side and multiplying total casualties by that ratio.

The level of observation for the DLEDB is the engagement, which often lasted more than one day. For this analysis, the data are expanded to the division by day level to make them more easily comparable to the division by day panel. The numbers of troops and tanks and the qualitative variables are assumed to be constant across days in the same engagement, and the

sorties, km of progress, and casualty figures are assumed to have been evenly distributed over the days of combat and are consequently divided by the number of days per engagement.

Table A2 shows the means and their standard errors for the engagement data. The means in column (1) are taken over the full sample of 289 division days. Column (2) shows a sample that excludes airborne observations. Column (3) shows a fixed effects sample that is restricted to those cases in which both the U.S. and the German divisions are observed in more than one engagement. The averages for the three samples are very similar, and the variables from these engagement data provide some new information about the nature of the operations. The U.S. division was the attacking unit roughly 90% of the time and tended to outnumber its opponent; the average U.S. division included 18,000 troops and 120 tanks, and the average German unit included 11,000 troops and 40 tanks. American forces tended to have the advantage (indices greater than one half) in all of the subjective indices except defender fortifications and tended to be successful in their missions, with an average mission accomplishment index of 0.54 to 0.56, average German KIA of 20 to 22 KIA relative to America's 13 to 14.

Cost Estimates

A third set of data sources is used in this study to estimate the dollar costs of raising and operating divisions of different types. The dollar costs of raising and operating organic infantry and armored divisions in WWII according to the 1942 organizations are estimated from a wide range of archival sources. The cost estimates take into account pay, training, item-specific purchase prices and capital depreciation rates, food, clothing, gasoline, ammunition, and transportation. These costs are then converted into a cost per troop and a cost per tank, so that they can be applied to the different types of units examined in this study. The cost per troop is

estimated as the cost of an organic infantry division divided by 15,514; hence, it represents the per troop cost of raising and operating a unit with no tanks and includes the costs of the equipment and vehicles associated with the unit. The cost per tank is estimated as the cost of an organic armored division minus 14,643/15,514 times the cost of an infantry division and divided by 390. Hence, the cost per tank takes into account the additional training costs and the additional vehicles, such as armored personnel carriers, that were associated with armored divisions. Results from the engagement data suggest that tanks were lost at a rate of roughly 35% per month for armored divisions relative to about 15% per month for infantry divisions, a finding that is consistent with the armored divisions' more intensive usage of tanks (results shown in the web appendix). To adjust for this discrepancy, a higher depreciation rate for tanks is assumed for armored divisions. Assuming time spent in the theater of 10.8 months (that of the average division), we estimate a total cost in 2009 dollars of $92,400 per troop and $5.84 million per tank, with an additional $1.63 million per tank used in an armored division.

For each division in the engagement data, the cost of a 10.8-month deployment is estimated by adding together the number of troops in the unit times the cost per troop and the number of tanks in the unit times the cost per tank. For the division by day panel, the numbers of troops and tanks typically associated with each unit type are measured using the published histories of attachments and detachments for each division in the ETO. These histories give the names and dates for each attached and detached unit; the numbers of troops and tanks in these units are identified from the U.S. Tables of Organization and Equipment. For foreign attachments, the numbers of troops and tanks are assumed to have been the same as comparable types of American units. The numbers of authorized troops and tanks in each pre- and post-

reorganization division type are then estimated by averaging by division type across the division days in the ETO. Additional details about these cost estimates appear in the web appendix.

Figure A1: Mission Accomplishment Worksheet

Engagement name:_______________________

Assessment date: _____ Assessor's Initials: _______

Attacker		Defender	
Conceptual Accomp:	0	Conceptual Accomp:	0
	1		1
	2		2
Geographical Accomp:	0	Geographical Accomp:	0
	1		1
	2		2
Block Hostile Missions:	0	Block Hostile Mission:	0
	1		1
	2		2
Command & Staff Perf:	0	Command & Staff Perf:	0
	1		1
	2		2
Troop Perf:	0	Troop Perf:	0
	1		1
	2		2
Bonus or Penalty:		Bonus or Penalty:	
Explain:		Explain:	
Total Score: _______		Total Score: _______	

Table A1: Descriptive Statistics from Division by Day Panel

Variable	(1) All Division Days	(2) Division Days with Axis Divisions in Cell ≥ 1: Full Sample	(3) Division Days with Axis Divisions in Cell ≥ 1: Fixed Effects Sample	(4) Division Days with U.S. KIA ≥ 5: Full Sample	(5) Division Days with U.S. KIA ≥ 5: Fixed Effects Sample	(6) Division Days from Engagement Data (Full Sample)
U.S. Km Geographical Progress per Day	2.605	1.229	0.860	2.060	1.445	1.879
	(0.099)	(0.125)	(0.189)	(0.149)	(0.270)	(0.440)
U.S. Killed in Action	5.016	8.25	7.74	19.41	17.69	20.19
	(0.096)	(0.248)	(0.507)	(0.334)	(0.572)	(1.503)
U.S. Died of Wounds	0.812	1.326	1.218	2.378	2.051	2.533
	(0.013)	(0.037)	(0.060)	(0.046)	(0.073)	(0.203)
Division is Armored	0.216	0.167	0.095	0.161	0.066	0.131
	(0.003)	(0.006)	(0.009)	(0.005)	(0.007)	(0.020)
Division is Infantry	0.719	0.760	0.860	0.799	0.912	0.834
	(0.003)	(0.006)	(0.010)	(0.006)	(0.008)	(0.022)
Division is Airborne	0.065	0.073	0.045	0.040	0.022	0.035
	(0.002)	(0.004)	(0.006)	(0.003)	(0.004)	(0.011)
Post-Reorganization Indicator	0.848	0.865	0.639	0.864	0.642	0.519
	(0.003)	(0.005)	(0.014)	(0.005)	(0.014)	(0.029)
Nearby Allied Divisions	0.889	1.582	1.823	1.254	1.283	1.450
	(0.011)	(0.024)	(0.051)	(0.024)	(0.049)	(0.103)
Nearby Allied Armored Divisions	0.172	0.293	0.304	0.268	0.215	0.266
	(0.003)	(0.009)	(0.019)	(0.008)	(0.015)	(0.027)
Nearby Axis Divisions	0.521	2.319	2.567	0.890	0.912	1.125
	(0.012)	(0.044)	(0.097)	(0.033)	(0.065)	(0.119)
Nearby Panzer Divisions	0.162	0.720	0.774	0.296	0.311	0.519
	(0.005)	(0.018)	(0.034)	(0.013)	(0.024)	(0.060)
Nearby SS or Parachute Divisions	0.089	0.398	0.408	0.166	0.166	0.208
	(0.003)	(0.011)	(0.022)	(0.008)	(0.014)	(0.034)
Location is North Africa	0.047	0.013	0.052	0.025	0.094	0.003
	(0.002)	(0.002)	(0.007)	(0.002)	(0.008)	(0.003)
Location is Italy	0.204	0.229	0.543	0.171	0.428	0.640
	(0.003)	(0.006)	(0.015)	(0.006)	(0.014)	(0.028)
Location is Northwest Europe	0.748	0.758	0.405	0.804	0.477	0.356
	(0.003)	(0.006)	(0.015)	(0.006)	(0.014)	(0.028)
Year (in days)	1944.8	1944.8	1944.4	1944.8	1944.4	1944.3
	(0.004)	(0.006)	(0.016)	(0.007)	(0.017)	(0.028)

Land Distance to Nearest Port (km)	528.3	487.7	335.8	491.1	365.8	294.1
	(1.952)	(3.562)	(7.345)	(3.817)	(7.845)	(12.55)
Average Slope >5 degrees	0.339	0.337	0.338	0.361	0.405	0.571
	(0.003)	(0.007)	(0.014)	(0.007)	(0.014)	(0.029)
Slope (degrees)	4.638	4.347	4.983	4.559	5.504	6.061
	(0.027)	(0.048)	(0.137)	(0.048)	(0.115)	(0.221)
Wet Days (Monthly)	14.04	14.50	12.14	14.47	12.08	13.95
	(0.03)	(0.07)	(0.15)	(0.07)	(0.16)	(0.30)
Monthly Precipitation (mm)	70.26	73.54	60.67	76.18	65.98	92.03
	(0.299)	(0.621)	(1.320)	(0.668)	(1.432)	(3.006)
Mean Temperature (Fahrenheit)	48.88	45.26	48.90	48.43	52.95	53.24
	(0.090)	(0.196)	(0.390)	(0.198)	(0.384)	(0.738)
Mean Temperature < 32°F	0.089	0.154	0.114	0.101	0.070	0.003
	(0.002)	(0.005)	(0.009)	(0.004)	(0.007)	(0.003)
Wooded or Mixed Vegetation	0.463	0.462	0.509	0.494	0.570	0.657
	(0.004)	(0.007)	(0.015)	(0.007)	(0.014)	(0.028)
Cultivated Land	0.359	0.327	0.161	0.326	0.198	0.069
	(0.003)	(0.007)	(0.011)	(0.007)	(0.011)	(0.015)
Prior Days in Theater	201.6	195.5	355.9	187.7	364.0	187.0
	(1.218)	(2.447)	(6.070)	(2.473)	(5.731)	(7.753)
Prior Days with ≥5 KIA	51.89	53.95	81.43	54.21	88.28	39.00
	(0.329)	(0.627)	(1.572)	(0.663)	(1.619)	(1.492)
N (Division Days)	19,721	4,430	1,137	4,579	1,221	289
Divisions	66	63	8	64	8	20

Notes to Table A1: Standard errors of the sample means shown in parentheses. Panels are unbalanced and include only those division days in which the unit was in a western theater and not at sea. Data sources and variable definitions are described in greater detail in the web appendix.

Table A2: Descriptive Statistics from Engagement Data

	Full Sample	Excluding Airborne	Fixed Effects Sample
U.S. Mission Accomplishment Index (Zero to One)	0.558	0.556	0.544
	(0.008)	(0.008)	(0.009)
U.S. Mission Success Indicator (Draw = 0.5)	0.673	0.663	0.640
	(0.026)	(0.027)	(0.030)
U.S. Distance Advanced (km)	0.887	0.994	1.070
	(0.136)	(0.133)	(0.159)
German Killed in Action (KIA)	21.72	21.67	20.42
	(1.647)	(1.691)	(1.839)
German Total Casualties (Killed, Wounded, and Captured)	211.3	212.5	204.4
	(15.92)	(16.37)	(18.97)
U.S. Killed in Action (KIA)	14.32	13.60	14.55
	(1.179)	(1.146)	(1.417)
U.S. Total Casualties (Killed, Wounded, and Captured)	152.3	147.7	154.3
	(9.773)	(9.405)	(11.57)
U.S. Division is Armored	0.131	0.136	0.067
	(0.020)	(0.021)	(0.017)
U.S. Division is Infantry	0.834	0.864	0.907
	(0.022)	(0.021)	(0.019)
U.S. Division is Airborne	0.035	0.000	0.027
	(0.011)	(0.000)	(0.011)
Post-Reorganization Indicator	0.519	0.502	0.502
	(0.029)	(0.030)	(0.033)
U.S. Troops	18,151	18,079	18,216
	(288.1)	(296.0)	(262.6)
U.S. Tanks	124.4	124.7	115.9
	(5.533)	(5.710)	(5.496)
U.S. Artillery	125.6	125.9	122.5
	(3.983)	(4.124)	(3.725)
U.S. Aerial Sorties	12.29	11.33	11.78
	(1.597)	(1.557)	(1.860)

German Unit is a Panzer Division	0.512	0.520	0.493
	(0.029)	(0.030)	(0.033)
German Unit is SS or Parachute	0.062	0.065	0.049
	(0.014)	(0.015)	(0.014)
German Troops	11,175	10,871	11,109
	(241.3)	(225.3)	(244.5)
German Tanks	41.48	38.77	38.19
	(2.101)	(1.935)	(2.034)
German Artillery	73.04	71.42	71.69
	(1.983)	(1.985)	(2.037)
German Aerial Sorties	4.215	2.971	4.147
	(0.827)	(0.593)	(0.946)
U.S. is Attacker	0.872	0.900	0.911
	(0.020)	(0.018)	(0.019)
Front Width (km)	10.07	9.518	10.40
	(0.364)	(0.294)	(0.444)
Location is North Africa	0.003	0.004	0.000
	(0.003)	(0.004)	(0.000)
Location is Italy	0.640	0.663	0.676
	(0.028)	(0.028)	(0.031)
Location is Northwest Europe	0.356	0.333	0.324
	(0.028)	(0.028)	(0.031)
Year (in days)	1944.3	1944.3	1944.3
	(0.028)	(0.028)	(0.031)
Mountain or River	0.215	0.222	0.231
	(0.024)	(0.025)	(0.028)
Rugged Terrain	0.490	0.507	0.516
	(0.029)	(0.030)	(0.033)
Wet or Rainy	0.334	0.332	0.307
	(0.024)	(0.024)	(0.026)
Cold Weather	0.462	0.443	0.440
	(0.029)	(0.029)	(0.033)

Wooded or Mixed Vegetation	0.910	0.907	0.889
	(0.017)	(0.017)	(0.021)
Urban or Conurban	0.042	0.044	0.054
	(0.009)	(0.009)	(0.011)
U.S. Advantage (0 to 1 Index) in Leadership	0.542	0.542	0.547
	(0.006)	(0.006)	(0.007)
U.S. Advantage (0 to 1 Index) in Training & Force Quality	0.562	0.562	0.573
	(0.009)	(0.009)	(0.011)
U.S. Advantage (0 to 1 Index) in Intelligence & Planning	0.516	0.517	0.511
	(0.003)	(0.004)	(0.003)
U.S. Advantage (0 to 1 Index) in Logistics & Reserves	0.529	0.530	0.536
	(0.005)	(0.005)	(0.005)
U.S. Advantage (0 to 1 Index) in Morale	0.544	0.544	0.549
	(0.006)	(0.006)	(0.007)
U.S. Advantage (0 to 1 Index) in Surprise	0.529	0.530	0.533
	(0.010)	(0.010)	(0.011)
U.S. Advantage (0 to 1 Index) in Defender Fortifications	0.201	0.190	0.180
	(0.016)	(0.016)	(0.018)
N (Division Days)	289	279	225
Clusters (Engagements)	162	152	132
Divisions	20	19	15

Notes to Table A2: Data source is the Division-Level Engagement Database (DLEDB). Standard errors of the sample means are shown in parentheses. Fixed effects sample excludes those observations in which the U.S. or German division only appears in one engagement. Mountain or River is determined based on the name of the engagement. Wooded or Mixed Vegetation and Urban or Conurban are each computed as the maximums of two separate indicator variables. All of the indices represent historians' subjective judgments and were converted by the author to span from zero to one. The indices for Training & Force Quality, Intelligence & Planning, and Logistics & Reserves are each computed as averages of two separate indices. The index for Surprise is computed from an indicator variable and as 1 if the U.S. was the surprising force, 0 if Germany was the surprising force, and 0.5 if there was no surprise. The index for Defender Fortifications is computed from an indicator variable and is 1 if the U.S. was the defender and fortifications were present, 0 if Germany was the defender and fortifications were present, and 0.5 if there were no fortifications.